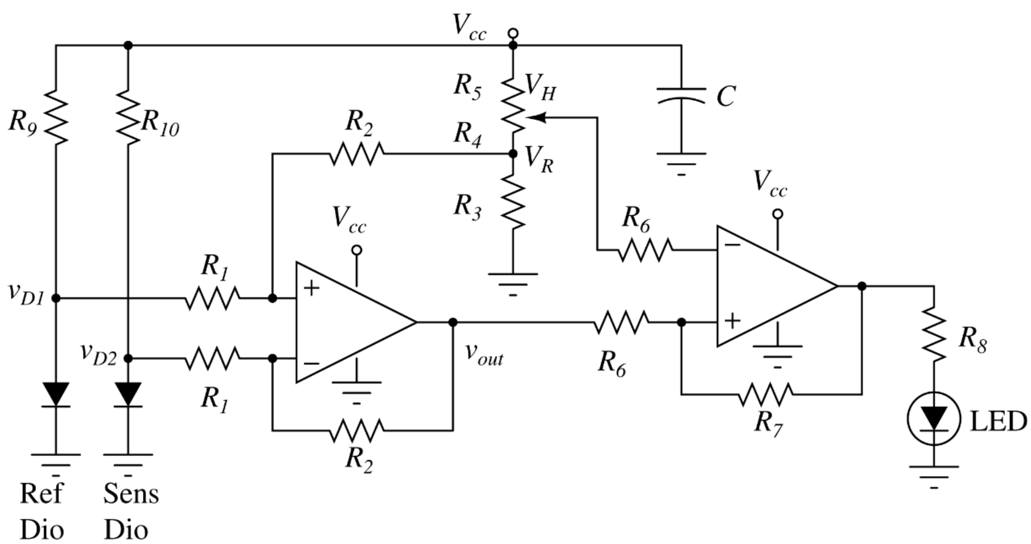
EE313 Laboratory #1 (v2)

Diode Characterization and Differential Temperature Sensor

A. Design a method to measure I_s of a p-n diode, 1N4148. The diode current is given by $I_D=I_s(e^{V_D/(nV_T)}-1)$ where n=1.752 and $V_T=kT/q$. For 1N4148, the maximum current should never exceed 50mA.

B. Design a differential temperature sensor using the temperature dependence of a diode forward voltage under constant current with the following specifications (all components in the room temperature, between 18°C to 28°C.). You may use the circuit recommended below (diodes are 1N4148. OPAMPs are LM358, two OPAMPs in the same package). You should use a single supply voltage of V_{cc} =mod(BilkentID,5)+10V. [mod(xx,5) is the remainder of xx after division by 5.]



Choose R_9 and R_{10} so the reference and sensor diodes have a current of about I_D=1mA.
$R_9=R_{10}=(V_{cc}-0.6)/(I_D)$.

The analysis of the difference amplifier gives:

$$v_{out}=(R_2/R_1)(v_{D1}-v_{D2})+V_R$$

The comparator analysis gives the two threshold voltages:
To turn on the LED, $v_{out}>V_H(R_7+R_6)/R_7$.
To turn off the LED, $v_{out}<V_H(R_7+R_6)/R_7-(R_6/R_7)(V_{cc}-2)$
Hence, the hysteresis value is $(R_6/R_7)(V_{cc}-2)$.

Choose $V_R=V_{cc}\,R_3/(R_3+R_4+R_5)$ assuming $R_2 \gg R_3$ (e.g., $R_2 \geq 20\,R_3$)
Use a multiturn pot of 10K for R_4+R_5 for a fine adjustment of V_H:
$V_H=V_{cc}\,(R_3+R_4)/(R_3+R_4+R_5)$

Choose (R_2/R_1) to give the required gain.
Choose the LED current limiting resistor to generate an LED current of 10mA: $R_8 \approx (V_{cc}-4)/0.01$

Choose the values of resistors so that they are all standard values (1, 1.2, 1.5, 1.8, 2.2, 2.7, 3.3, 3.9, 4.7, 5.6, 6.8, 8.2). If you need to tune a value, insert a parallel resistor (rather than a series resistor).

1. When both diodes are at room temperature (v_{D1}=v_{D2}), the output voltage, v_{out}, should be at (V_{cc}−2)/4
2. The output voltage should show the temperature difference between the room temperature and the temperature of the sensor diode in degrees with a 10% tolerance. For example, if the sensor diode is +1-degree warmer, v_{out} should change by +1V.
3. A red LED should turn on when the sensor's temperature exceeds +5±0.5°C the room temperature.
4. The LED should never flicker around the thresholds: It should have a 0.1°C (0.1V) hysteresis.

Preliminary work (Due Sept. 29, 2024)

A. Simulate your method using LTSpice to determine the I_s of the diode.
B. Show using LTSpice and 1N4148 diode, that I_s value found is nearly equal to the spice model value of 2.52nA. Note that 1N4148 diode is modeled in LTSpice as
   I_d=I_s ($e^{V_d/(nV_T)}$-1) where n=1.752 and V_T=kT/q.
C. Using LTSpice, show that when both sensors are at 18°C and 28°C, the output voltage is nearly (V_{cc}−2)/4 ±0.3V.
D. Using LTSpice, show that the output voltage, v_{out}, increases by 1±0.1 V/°C by sensor temperature when the room temperature is at 23°C.
E. Using LTSpice, show that LED voltage goes high when the sensor's temperature increases to +5±0.5°C above the room temperature of 23°C. You can use the L128-DRD1003500000 component in LTSpice diode library with a current limiting resistor, R_8, in series. LED is assumed to be on when a current flows through it.
F. Using LTSpice, show that LED voltage goes low when the sensor’s temperature is reduced to 0.1°C below its turn-on point.

The default temperature of simulation in LTSpice is 27°C. This can be changed, for example, to 22°C by adding the spice directive

.temp 22

LTSPICE allows the device temperature of a component to be set. However, this possibility is not described in the documentation. Control right-click on the diode body and add “temp={t1}” to one of the empty attribute fields after the diode model name (for example, Value2). Then add

.step param t1 begin end stepsize

Spice directive to see the response as a set of curves with different temperatures.

Provide a schematic of your design, showing a component list. Use Diptrace to generate the schematic. Refer to the Diptrace Tutorial.

Upload your report containing the schematic as a pdf file. Then upload the LTSpice .asc file.

Experimental work (Due Oct. 6, 2024)

A. Apply your method to measure I_s of a 1N4148 diode.

B. Build your temperature sensor design on a breadboard. You may use a resistor in physical contact with the sensor diode and insulate it with electrical tape to adjust the sensor temperature. The resistor may be connected to a separate adjustable voltage source to heat the sensor in a controlled manner. Connect your multimeter to the output. Show that it satisfies all the specifications. It is always a good idea to place a decoupling capacitor (C=100nF) between the supply voltage and the ground. You may use a thermocouple provided with many multimeters to measure the room and sensor temperatures and calibrate the resistive heater.

   Upload pdf report.

Grading criteria:

Preliminary work (10 pts)

I_s measurement method with LTSpice simulation: 1pt

Nice looking temperature sensor schematic with component list: 1pt

Satisfaction of all four criteria in LTSpice: 8pts, 2 pts each

Experimental work (10 pts)

I_s measurement: 1pt

A neat, easy-to-follow, and easy-to-debug circuit implementation on the breadboard. 1pt

Experimental satisfaction of all four criteria: 8 pts, 2pts each